REMARKS

Claims 1-2 and 4-15 remain pending after response.

Claim Amendments

Claim 7 is amended in order to more clearly define the claimed invention. Support for the noted amendment resides at page 5, lines 3-5 of the specification. The thermal spray coating film 3 at page 5, line 3 corresponds to the inventive thermal spray coating, and the hard chromium plating film at page 5, line 4 corresponds to the lower coating layer. The Examiner contends that claim 7 is directed to application of a thick coating layer. However, as is made clear by the amendment of claim 7, the formation of a thick coating layer is not contemplated in claim 7. Claim 3 is cancelled. No new matter is added by this amendment.

Withdrawal of Claims 14-15

The Examiner withdraws claims 14 and 15 from consideration. The basis for this action on the part of the Examiner is that "this invention has been constructively elected by original presentation for prosecution on the merits. Accordingly, claims 14-15 have been withdrawn from consideration as being directed to a non-elected invention."

Applicants traverse the withdrawal of claims 14-15 for the reason that the subject matter claimed therein does not differ significantly from that claimed in claim 7 (which has been examined). Applicants thus request rejoinder of claims 14-15 with the examined claims.

Rejection under 35 USC 112 (paragraph two)

Claim 7 stands rejected under 35 USC 112 (paragraph two) as not distinctly claiming the invention. In response, claim 7 is amended in a manner which is believed to overcome the rejection. The rejection is thus believed to be moot, and should be withdrawn.

Rejection of Claims 1-13 under 35 U.S.C. 103(a)

Claims 1-13 are rejected under 35 U.S.C. 103(a) over McCune et al in view of Mori. This rejection is respectfully traversed.

By way of review, the present invention is directed to a thermal spray coated piston ring which is provided with a thermal spray coating film containing from 2-40 mass % of Sn, 5-50 mass % of graphite and the balance consisting essentially of Cu. Applicants' invention is neither disclosed nor suggested by the cited prior art.

The McCune reference is directed to a method for thermally spraying metal/solid lubricant composites. The reference teaches at column 2, lines 60-64 that the disclosed method may be used for depositing a simulated cast iron coating which contains graphite onto a variety of substrates such as automotive components, such as components comprised of aluminum, magnesium-based alloys, or iron-based alloys.

Claim 2 of the patent is directed to a method of making a lightweight engine block for an internal combustion engine having at least one chamber for containing movement of a thrust element. The interior of the chamber may be thermally coated with a graphite-based coating.

The Examiner acknowledges that McCune does not expressly teach the coating of a piston ring as claimed by applicants. However, the Examiner takes the position that "it would

have been obvious to one of ordinary skill in the art at the time of the invention to have formed the spray coating of McCune on any automotive engine component that would benefit from having such a coating including piston rings."

The Examiner also acknowledges that McCune does not expressly teach the claimed composition of the copper-tin alloy containing graphite lubricant particles. However, the Examiner relies on the Mori patent to cure this deficiency.

More specifically, Mori states as follows at column 1, lines 7-16 regarding the composition of the alloy coating:

> "To this end, according to one aspect of the invention, there is provided a sliding material having a back metal layer and a graphite-containing phosphor bronze sintered layer bonded to the back metal layer, the graphite-containing phosphor bronze sintered layer consisting essentially of 0.03 to 1 wt % phosphorus, 7.5 to 16 wt % tin, 1 to 8 wt % graphite and the balance copper, and being constituted by phosphor bronze powder passing through a 200-mesh screen and a graphite powder passing through a 350-mesh screen".

The Mori layer contains 7.5 to 16 wt % tin, which the Examiner concludes is within the scope of 2-40 mass % of Sn. The Mori layer contains 1 to 8 wt % graphite, which the Examiner concludes is within the scope of 5-50 mass % of graphite. The Mori layer contains the balance copper, which the Examiner concludes is within the scope of the balance copper of the present invention.

In response, applicants note that thermally sprayed piston rings have been known for many years. The Examiner relies on the teachings of the McCune reference to teach thermal spraying. McCune states "This method is particularly useful in depositing a simulated cast iron coating containing graphite onto metal substrate, such as automotive components made of aluminum, magnesium-based alloys, or iron-based alloys." The McCune reference is related to

thermal spray cast iron applied on the aluminum cylinder bore. McCune, however, does not suggest such a method with piston rings.

In addition, since cast iron is used with piston rings as shown by the attached RIKEN Corporation "Piston Ring and Seal Ring Handbook" (published 1996), there is no incentive to thermal spray cast iron onto the piston ring. One of ordinary skill in the art would not try to thermal spray as taught by McCune, as one of ordinary skill in the art would simply employ cast iron piston rings, as opposed to thermal sprayed piston rings. The Examiner's attention is directed to pages 7-18 which illustrate materials for piston rings, and pages 19-24 which illustrate surface treatments.

Mori discloses a sintered layer rather than a spray coated layer. As discussed above, the Examiner relies upon the teachings of the McCune reference for teaching thermal spraying. However, the Examiner has not provided the necessary motivation to use the thermal spray coating of McCune for sintering as in Mori. The Examiner states that the motivation for using thermal spraying is to form a more adherent coating. However, applicants do not agree that such motivation is sufficient to combine the teachings of the references in order to yield the present invention.

Applicants question that applicability of the teachings of Mori at column 1, line 12 regarding a "piston ring". The corresponding Japanese application No. 58-48975 contains no mention of a piston ring, with the corresponding portion of the Japanese application stating as follows:

> "The present invention relates to a composite material having a graphite-containing phosphor bronze sintered layer suitable for use as material for a bush and a washer employed for bearings and so forth in automobile, industrial machinery and agricultural machinery."

It is thus clear that no mention is made of a piston ring. Furthermore, the piston ring, which consists of the back metal and the sintered powder layer on the back metal, is not described in the RIKEN handbook. Applicants thus question whether Mori sufficiently describes the invention in relation to use with a piston ring such that one of ordinary skill in the art would appreciate that the invention of Mori includes a novel sintered piston ring.

Further, modifying the teachings of Mori in the manner suggested by the Examiner would, in applicants' view, destroy the teachings of Mori.

More specifically, the coating of the Mori reference is not a thermal spray coating. Rather, the coating of the Mori reference is a sintered one having a porous microstructure. The porous microstructure holds or stores oil within it, which is an essential feature (e.g. oil impregnation) of the bush and washer employed for bearings. In this regard, see column 9, lines 59-62 of U.S. Patent 4,430,386, which is a main application of the Mori reference. Since the raw materials used in the prior art are coarse particles, the binding strength among the powder particles is small and the resulting alloy has poor bending properties and toughness. In order to solve this problem, Mori proposed that fine particles such as phosphor-bronze alloy powder which passes through a 200-mesh screen and graphite powder which passes through a 350-mesh screen be used to improve mechanical properties such as tensile strength, bonding strength and the hardness of the alloy layer. The use of fine particles increases the contact points of the particles in order to improve the mechanical properties. Porosity of the alloy layer is controlled by the sintering process such as control of the sintering temperature.

In view of the discussion above - and contrary to the position taken by the Examiner- if the thermal spraying of McCune was applied to the invention of Mori, the resulting powder

particles of Mori would be melted and sprayed onto a substrate and immediately freeze and form a coating of deformed particles in a lamellar structure. See col. 1, lines 15-20 of the McCune reference. The Examiner should further note that in the thermal spraying process it is difficult to control the porosity of the alloy layer. Also, the microstructure strongly affects the mechanical properties of the sliding materials. Thus, it is readily apparent that the intended microstructure and mechanical properties of Mori could <u>not</u> be obtained by the McCune thermal spraying process.

Indeed, Mori describes the following method for making a sliding member:

> "To this end, according to another aspect of the invention, there is provided a method of manufacturing a sliding material, the method comprising the steps of providing a phosphor-bronze alloy powder which is passed by a 200 mesh screen and a graphite powder which is passed by a 350 mesh screen; providing a mixed powder having a composition consisting essentially of 0.03 to 1 wt.% phosphorus, 7.5 to 16 wt.% tin, 1 to 8 wt. % graphite, and the balance copper by mixing the phosphor-bronze alloy powder and the graphite powder; spreading the mixed powder on a back metal layer and then sintering the mixed powder to form a composite layer; and rolling the composite powder constituted by sintered mixed powder layer and the back metal layer to form a composite material for a sliding member having a predetermined thickness."

If this method is used for producing a piston ring, the sintered product is bent in such a manner that the sintered layer is positioned on the outer circumferential side. The Examiner's attention is directed to the attached drawing appendix in this regard.

Therefore, tensile residual stress is generated in the sintered layer. Meanwhile, when a bearing is produced by the method of Mori, compressive residual stress is generated in the heat sintered layer. This is advantageous from the standpoint of strength. It would be easy to anticipate the technical inconvenience of Mori, when applied to a piston ring. As such, it is

unlikely that the invention of Mori would be seen by one of ordinary skill in the art as being rationally applicable to piston rings as asserted by the Examiner.

Clearly then, the combination of the teachings of the Mori and McCune references would not result in the present invention. Moreover, modifying the teachings of the references in the manner suggested by the Examiner would destroy the intended purpose or function of the references. Further, there is no motivation for modifying the teachings of the references in the manner suggested by the Examiner in order to obtain the present invention. The Examiner's position to the contrary represents a hindsight reconstruction of the prior art in view of applicant's own disclosure.

The rejection is thus without basis and should be withdrawn. The application is accordingly believed to be in condition for allowance, and an early indication of same is earnestly solicited.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Marc S. Weiner (Reg. No. 32,181) at the telephone number of the undersigned below, to conduct an interview in an effort to expedite prosecution in connection with the present application.

A check in the amount of $120.00 is attached as payment for the requested one month extension of time.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37.C.F.R. §§1.16 or 1.14; particularly, extension of time fees.

Dated: JUL 2 0 2006

Respectfully submitted,

By

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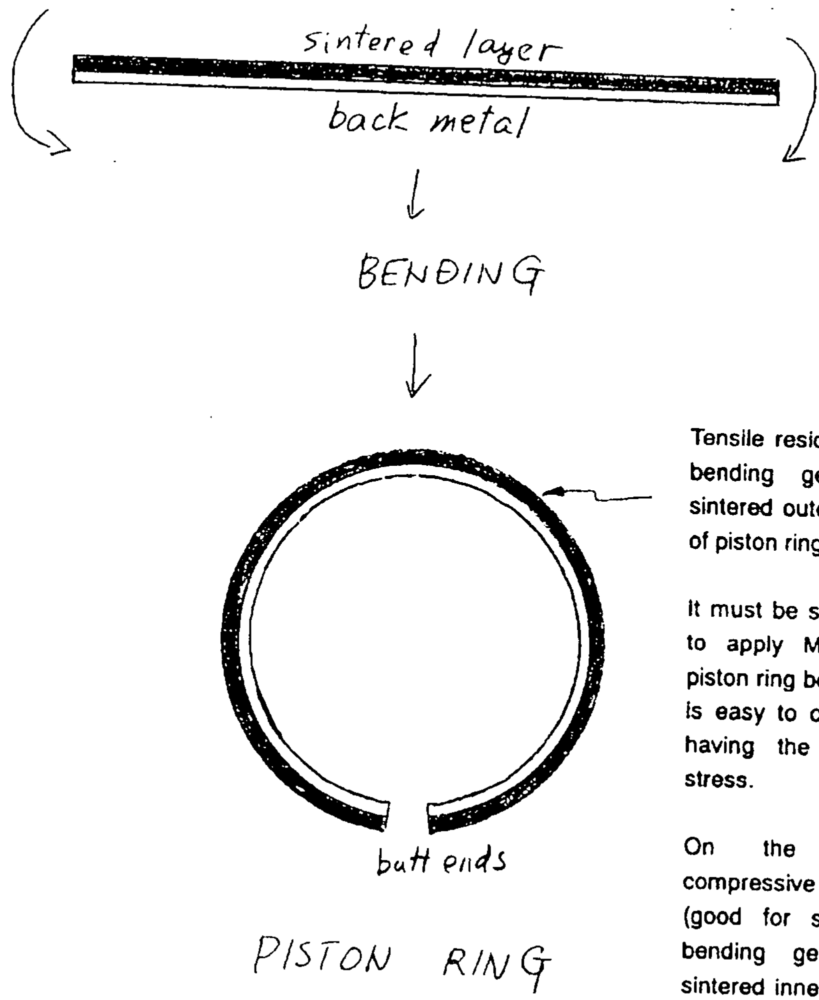
Attachments: Drawing appendix
RIKEN brochure

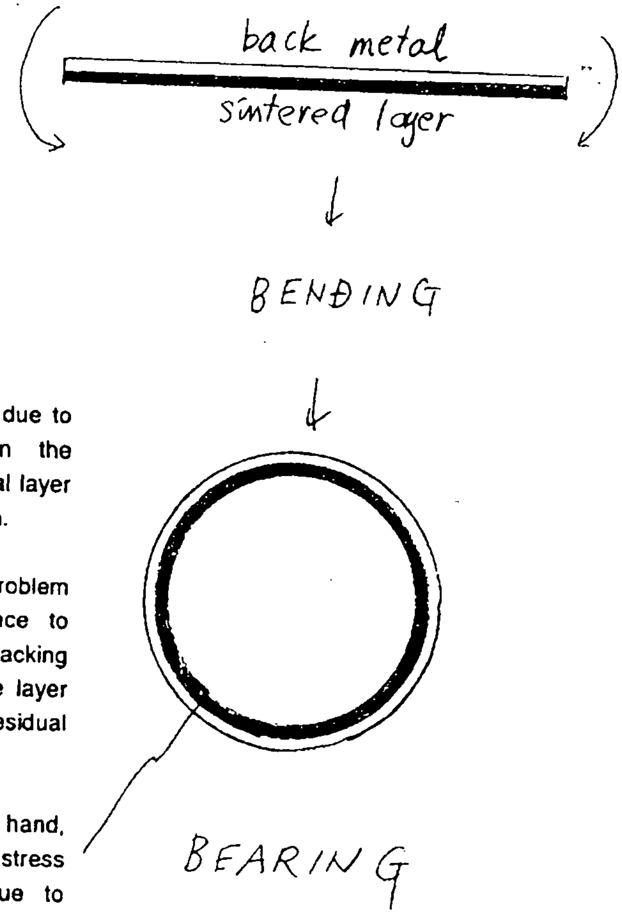
APPENDIX



Tensile residual stress due to bending generates in the sintered outer peripheral layer of piston ring application.

It must be significant problem to apply Mori reference to piston ring because a cracking is easy to occur in the layer having the tensile residual stress.

On the other hand, compressive residual stress (good for strength) due to bending generates in the sintered inner peripheral layer of bearing application.



PISTON RING
AND SEAL RING HAND BOOK

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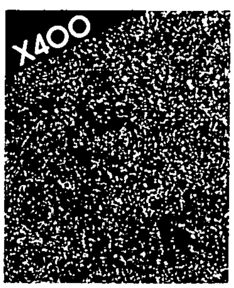
3. PISTON RING & SEAL RING MATERIALS

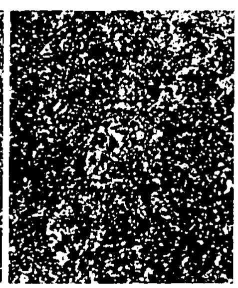
Steel

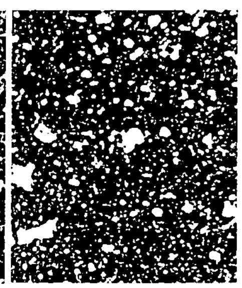
RIK-SP is specially sélected and improved steel which is ideally suited for use as piston ring material. It is used for the side rails of pressure rings and composite oil rings for high speed small engines. When RIK-SP is used for lead-fuel gasoline engines and small diesel engines, it gives better performance than conventional hard chromeplated materials thanks to the improved properties attained by surface treatment. RIK-SS gives excellent workability, spring **RIK-SS** gives excellent workability, spring characteristics, heat resistance and fatigue resistance. Therefore, it is used as spacer materials for composite oil rings.

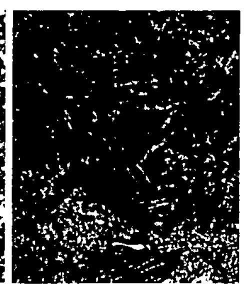
Material	Piston Ring Characteristics		Chemical composition (%)										Applications
	Transverse Rupture Strength (MPa)	Hardness (Hv)	C	Si	Mn	P	S	Ni	Cr	Mo	V	Others	
RIK.SP-1 Spring steel	1373	400~ 580	0.74~ 0.90	0.35 max.	0.60 max.	0.030 max.	0.030 max.						Rails for RIK VENT, DIESEL VENT-M, plate expanders, coil springs
RIK.SP-2 Spring steel	1471	450~ 570	0.50~ 0.60	1.20~ 1.60	0.50~ 0.80	0.025 max.	0.025 max.		0.50~ 0.80			Cu 0.2 max.	High-perfomance pressure ring, plate expanders
RIK.SP-3 Stainless steel	1128	300~ 420	0.80~ 0.95	1.00 max.	1.00 max.	0.040 max.	0.030 max.		17.00~ 18.00	1.00~ 1.25	0.08~ 0.15		Special-purpose pressure rings rails for RIK VENT (Used after nitriding)
RIK.SP-5 Tool steel	1471	440~ 580	0.32~ 0.42	0.80~ 1.20	0.50 max	0.030 max.	0.030 max.		4.50~ 5.50	1.00~ 1.60	0.50~ 1.20		Special-purpose pressure rings
RIK-SP-6 Stainless Steel	981	250~ 370	0.26~ 0.40	1.00 max.	1.00 max.	0.040 max.	0.030 max.	0.60 max.	12.00~ 14.00				Special-purpose pressure rings DIESEL VENT-M (Used after nitriding)
RIK.SP-11 Spring steel	1373	400~ 520	0.74~ 0.81	0.15~ 0.35	0.60~ 0.90	0.030 max.	0.030 max.						DIESEL VENT-M
RIK.SS-1 Stainless steel	882	250~ 400	0.08 max.	1.00 max.	2.00 max.	0.045 max.	0.030 max.	8.00~ 10.50	18.00~ 20.00				Spacers for RIK VENT-S coil springs, RIFLON lined rings
RIK.SS-2 Stainless steel	1078	300~ 450	0.09 max.	1.00 max.	1.00 max.	0.040 max.	0.030 max.	6.50~ 7.75	16.00~ 18.00			Al 0.75~1.50	Spacers for RIK VENT-U (Used after nitriding)
RIK.SS-3 Stainless steel	1078	385~ 485	0.15 max.	1.00 max.	5.50~ 7.50	0.060 max.	0.030 max.	3.50~ 5.50	16.00~ 18.00			N 0.25max.	Spacer for RIKFLEX

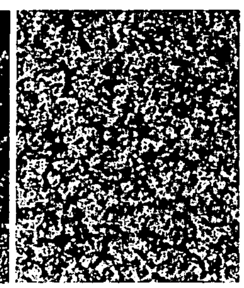


RIK-SP-1


RIK-SP-2

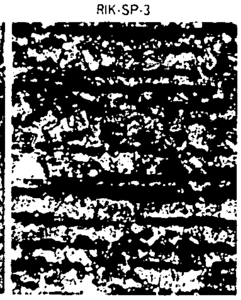

RIK-SP-3


RIK-SP-5


RIK-SP-6


RIK-SP-11


RIK-SS-1


RIK-SS-2


RIK-SS-3

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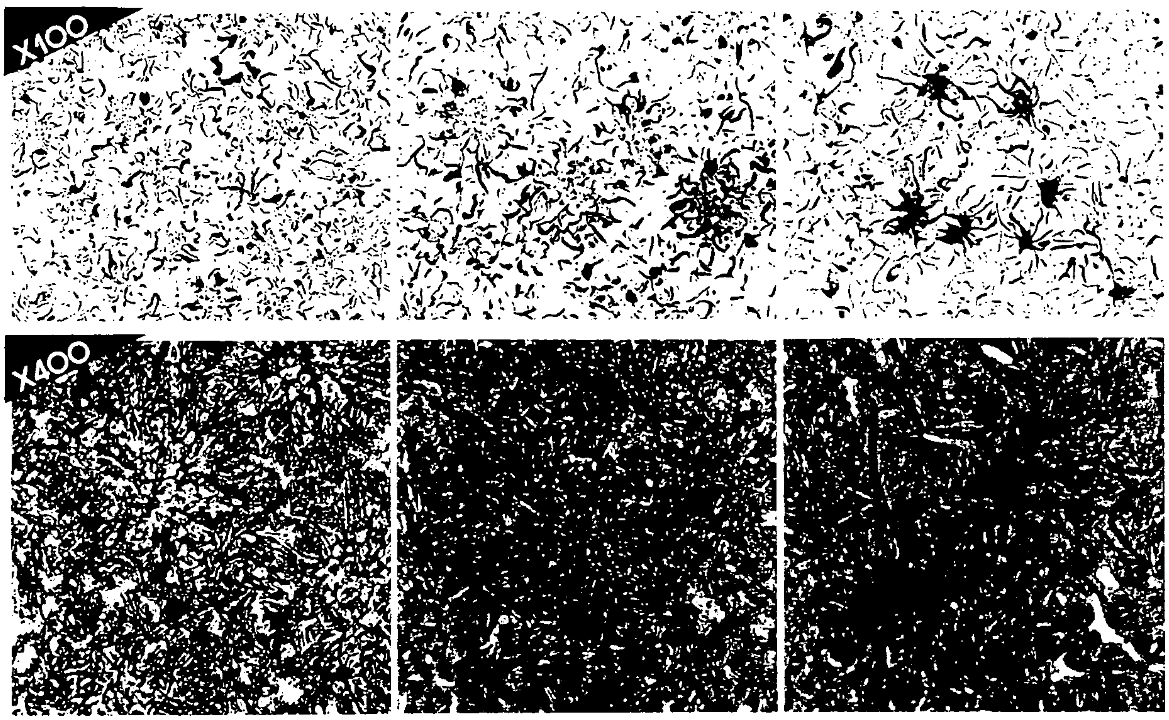
RIK-A (RIK-A 10, 11, 12)

RIK-A is alloy gray cast iron in which fine graphite is distributed uniformly in the bainite structure. Alloy elements such as nickel, molybdenum, vanadium, chromium, etc. are added. This material has high hardness (500HV), excellent wear-, break-and heat-resistance.

RIK-A has better resistance to beating wear and breakage because it has relatively high modulus of elasticity and hardness. Consequently, it is suitable for the 1st ring in high speed, high power engines and piston rings subject to severe operating conditions such as for construction equipment.

Material	Applicable Piston Ring Size (mmφ)	Pistion Ring Characteristics				Chemical Composition (%)										Application
		Modulus of Elasticity (GPa)	Transverse Rupture Strength (MPa)	Hardness HRB	Tension Decrease (%)	T.C.	Si	Mn.	P	S	Cr	Ni.	Mo	Cu	V	
RIK-10	Less than 160	118	490 min.	108 ~ 114	8 max.	3.0 ~ 3.5	2.2 ~ 3.2	0.4 ~ 1.0	0.2 max.	0.12 max.	0.1 ~ 0.3	0.8 ~ 1.2	0.8 ~ 1.2	—	0.05 ~ 0.20	Ring for automobile gasoline engine
RIK-11	Less than 160	108	441 min.	102 ~ 110	8 max.	3.0 ~ 3.5	2.0 ~ 2.8	0.4 ~ 1.0	0.3 max.	0.12 max.	0.5 max.	—	0.5 ~ 1.2	0.5 ~ 1.2	—	Compression ring and oil control ring for small size Diesel engine
RIK-12	Less than 160	93	441 min.	98 ~ 110	8 max.	3.4 ~ 3.9	2.2 ~ 3.1	0.4 ~ 1.0	0.3 max.	0.12 max.	0.5 max.	—	0.5 ~ 1.2	0.5 ~ 1.2	—	



RIK-10: Uniform distribution of fine graphite in the tempered martensite or bainite structure.

RIK-11: Uniform distribution of fine graphite in the tempered martensite or bainite structure.

RIK-12: Uniform distribution of fine graphite in the tempered martensite or bainite structure.

HI-RIK (RIK-20, 20A, 21, 21A, 22, 23, 24, 25, 26, 29, 29V)

HI-RIK is a high elastic material and it shows a modulus of elasticity of 147 to 167 GPa which is close to steel modulus of elasticity 196GPa. The reason for this is that the configuration of graphite (nodular and tempered) shows low notch effect.

HI-RIK has excellent wear resistance which is top ranked among currently available cast iron types. In particular, **RIK-25** is of the highest quality, hardness is 35 to 48HRC and the modulus of elasticity is 167GPa **HI-RIK** is suitable for such applications as automobiles, vessels, construction equipment, aircraft which require high modulus of elasticity and break-resistance.

Material	Pistion Ring Characteristics					Chemical Composition (%)										Application
	Applicable Piston Ring Size (mmϕ)	Modulus of Elasticity (GPa)	Transverse Rupture Strength (MPa)	Hardness	Tension Decrease (%)	T.C.	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	
RIK-20	up to 100 100~200	167 157	100 min.	HRB 100~110	7 max.	3.5~4.2	2.2~3.4	0.2~0.8	0.2 max.	0.02 max.	—	—	—	—	—	Chromium plated 1st ring for small size, high engine
RIK-20A	up to 100 100~200	167 157	100 min.	HRC 25~38	7 max.	3.5~4.2	2.2~3.4	0.2~0.8	0.2~max.	0.02 max.	—	—	—	—	—	Chromium plated 1st ring for small size, high speed Diesel engine
RIK-21	200 min.	157	100 min.	HRB 98~108	7 max.	3.3~4.0	2.0~3.2	0.2~0.8	0.2 max.	0.02 max.	—	—	—	—	—	Chromium plated 1st and 2nd rings for medium size, medium speed engine Piston ring for piling hammer and air hammer
RIK-21A	200~400	157	100 min.	HRC 25~38	7 max.	3.3~4.0	2.0~3.2	0.2~0.8	0.2 max.	0.02 max.	—	—	—	—	—	1st ring and high wall pressure oil scraper ring for medium size, medium speed internal combustion engine
RIK-22	up to 200	147	95 min.	HRB 96~107	7 max.	2.5~3.3	0.9~1.7	0.4~1.0	0.3 max.	0.12 max.	0.1 max.	—	—	—	—	1st ring for aircraft engine and small size, high speed Diesel engine
RIK-23	up to 200	157	100 min.	HRB 95~105	7 max.	3.0~4.0	4.0~5.5	0.4 max.	0.2 max.	0.02 max.	—	—	—	—	—	Seal rings for exhaust pipe
RIK-24	up to 400	167	100 min.	HRC 25~38	7 max.	3.5~4.2	2.2~3.4	0.2~0.8	0.2 max.	0.02 max.	—	—	0.5~1.0	0.5~1.0	—	1st ring for Diesel engine
RIK-25	up to 200	167	100 min.	HRC 35~48	5 max.	3.5~4.2	2.2~3.4	0.2~0.8	0.2 max.	0.02 max.	—	—	0.5~1.0	0.5~1.0	—	1st ring for small size, high speed Diesel engine
RIK-26	up to 200	147	80 min.	HRC 25~38	7 max.	2.7~3.5	1.3~2.1	0.5~1.2	0.3 max.	0.12 max.	0.1~0.6	—	0.1~0.6	0.3~0.8	—	1st ring for Diesel engine
RIK-29	400 min.	147	80 min.	HB 250~320	7 max.	3.2~4.0	1.0~1.8	0.3~0.7	0.1 max.	0.015 max.	0.05~0.9	0.5~2.5	—	0.5~3.0	—	1st ring for Marine Diesel engine
RIK-29V	400 min.	147	80 min.	HB 250~320	7 max.	3.2~4.0	1.0~1.8	0.3~0.7	0.1 max.	0.015 max.	0.05~0.9	0.5~2.5	—	0.5~3.0	0.1~0.3	1st ring for Marine Diesel engine

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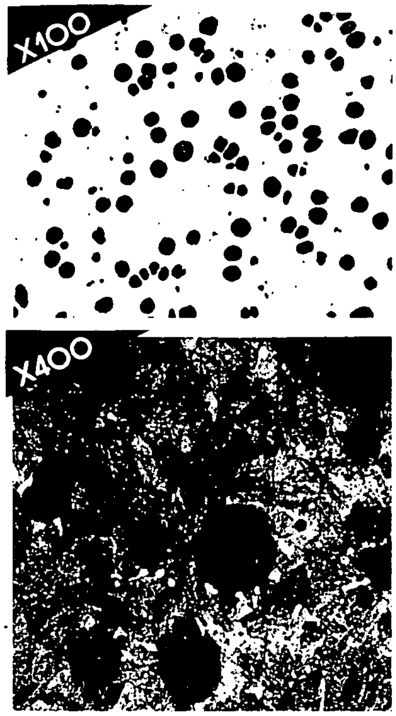
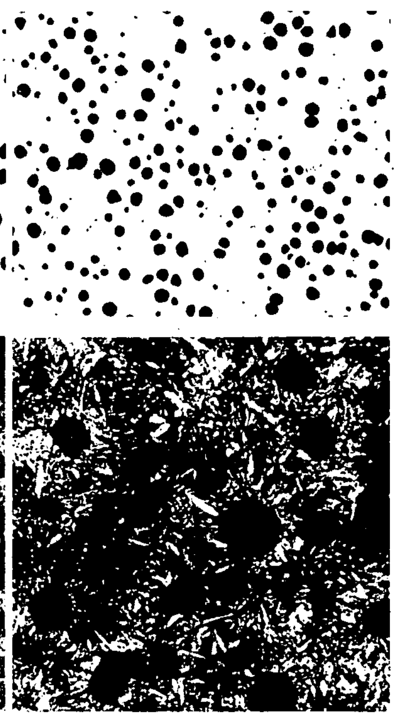
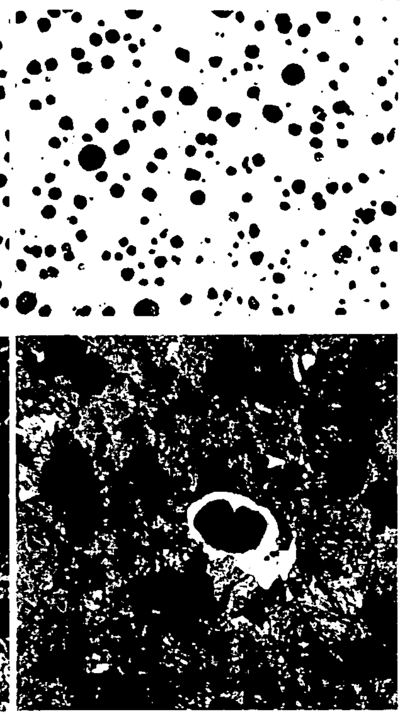
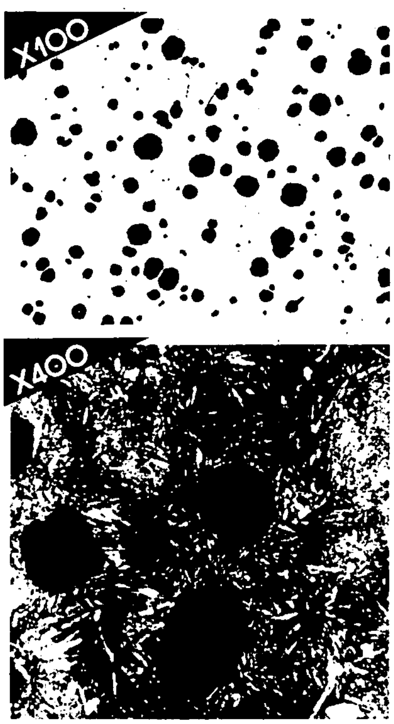


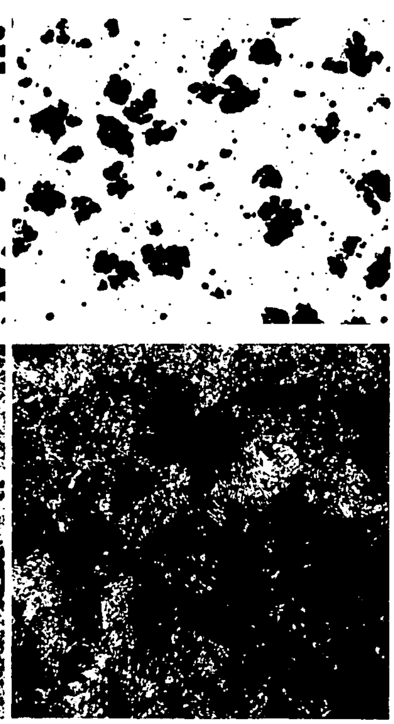
RIK-20: Uniform distribution of nodular graphite in the pearlite structure.

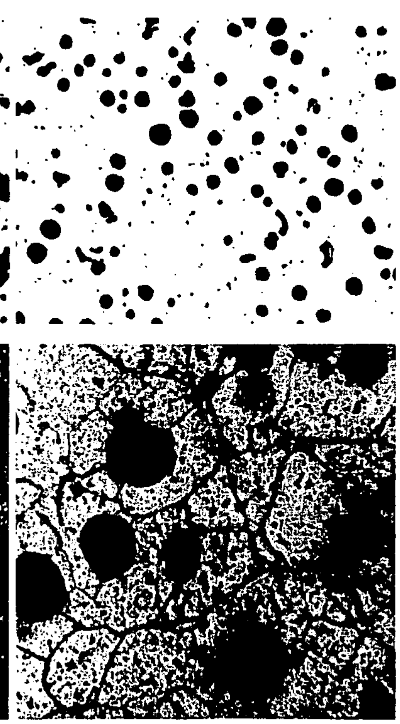

RIK-20A: Uniform distribution of nodular graphite in the tempered martensite or bainite structure.

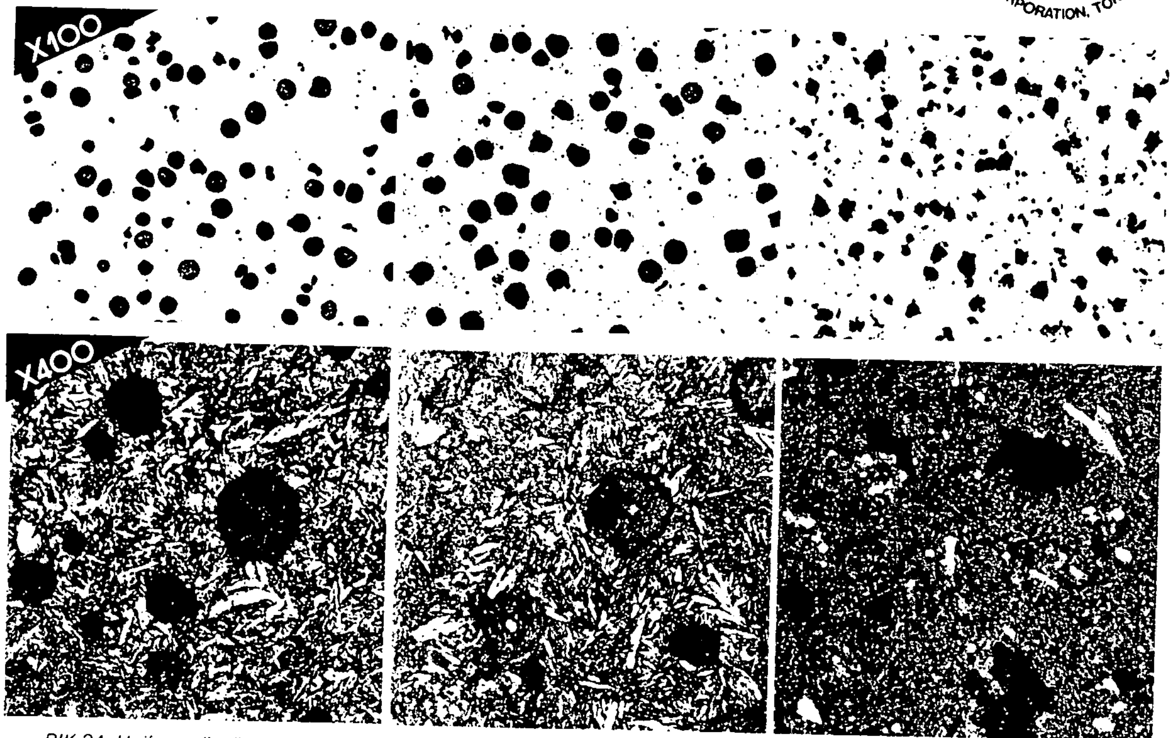

RIK-21: Uniform distribution of nodular graphite in the pearlite structure.



RIK-21A: Uniform distribution of nodular graphite in the tempered martensite or bainite structure.


RIK-22: Uniform distribution of tempered graphite in the pearlite structure.

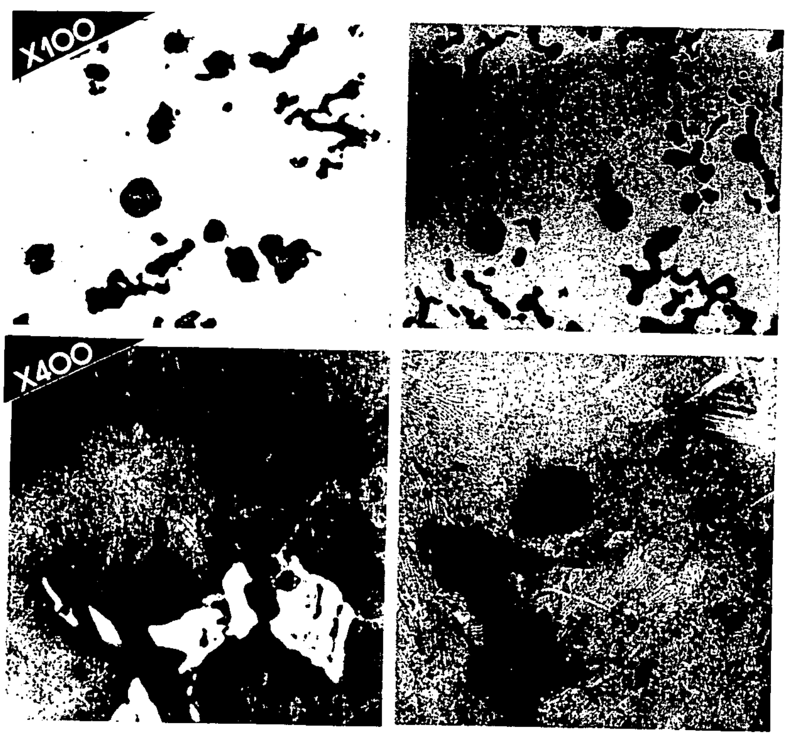

RIK-23: Uniform distribution of nodular graphite in the silicon rich ferrite structure.



RIK-24: Uniform distribution of nodular graphite in the tempered martensite or bainite structure.

RIK-25: Uniform distribution of nodular graphite in the tempered martensite or bainite structure.

RIK-26: Uniform distribution of fine graphite and carbide in the pearlite structure.



RIK-29: Uniform distribution of vermicular graphite and carbide in the pearlite structure.

RIK-29V: Uniform distribution of vermicular graphite and carbide in the pearlite structure.

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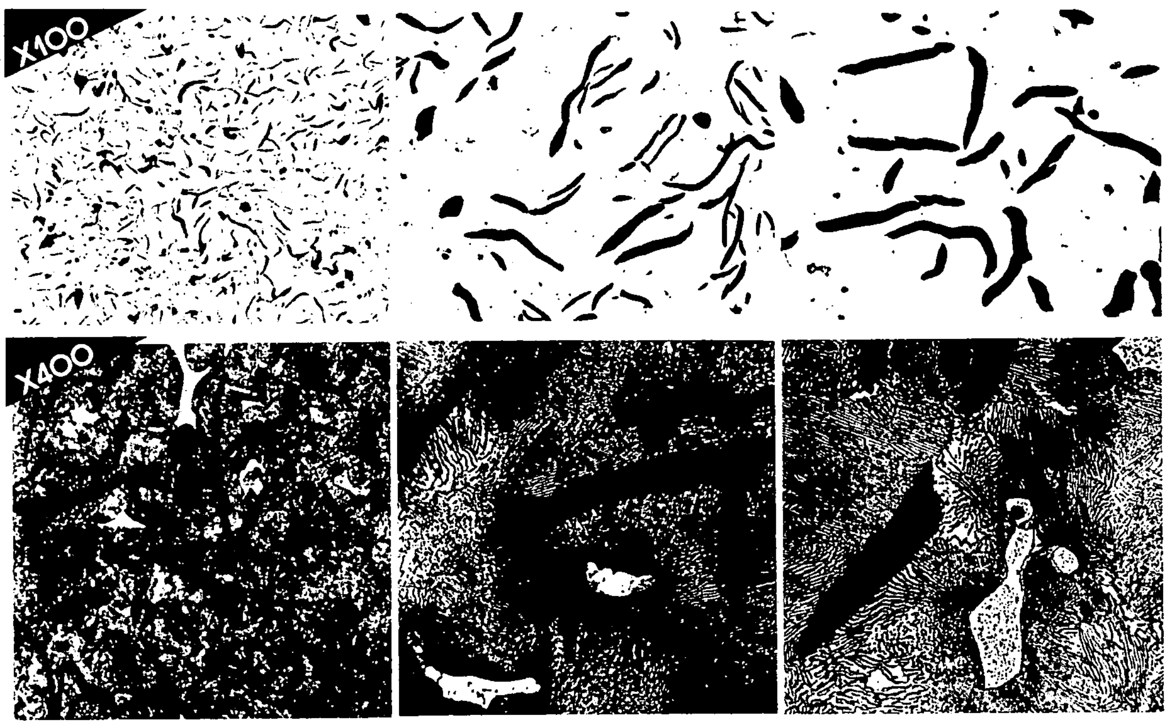
RIK-DITE (RIK-30, 31, 32)

In **RIK-DITE**, compound carbide is distributed uniformly in the pearlite structure together with graphite which gives self-lubrication.
Special elements such as phosphorous, vanadium, titanium, chromium, etc. form a compound carbide, which then forms hard spots and reduces wear.

Generally, **RIK-DITE** is suitable for engines in automobiles, vessels, and agricultural machinery. In particular, it has good correlation with cylinder materials which have compound carbide including vanadium, and shows good durability.

Material	Pistion Ring Characteristics					Chemical Composition (%)										
	Applicable Piston Ring Size (mmϕ)	Modulus of elasticity (GPa)	Transverse Rupture Strength (MPa)	Hardness	Tension Decrease (%)	T.C.	Si	Mn	P	S	Cr	Ni	Mo	Ti	V	Application
RIK-30	up to 200	108	343 min.	HRB 95~107	10 max.	3.3~4.0	2.0~3.2	0.5~1.0	0.4~0.8	0.12 max.	0.5 max.	—	—	0.1 max.	0.05~0.20	Automobile, agricultural machinery
RIK-31	200~400	118	441 min.	HRB 85~100	15 max.	2.8~3.4	1.6~2.6	0.5~1.0	0.3~0.8	0.12 max.	0.5 max.	—	—	0.1 max.	0.08~0.20	Marine Diesel engine
RIK-32	400 min.	123	441 min.	HB 178~235	15 max.	2.8~3.4	1.1~2.1	0.5~1.0	0.3~0.8	0.12 max.	0.5 max.	—		0.1 max.	0.08~0.20	Marine Diesel engine



RIK-30: Uniform distribution of massive or flake graphite and compound carbide with P and V in the pearlite structure.

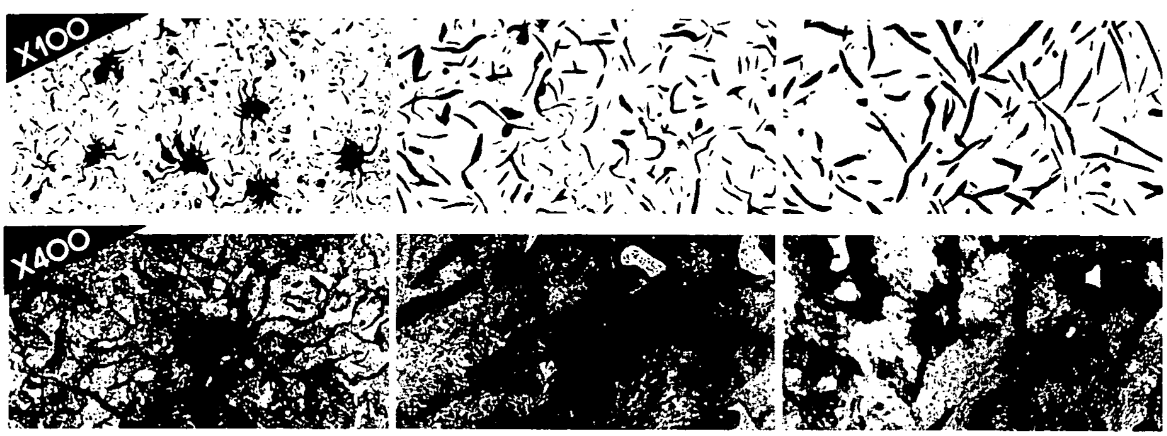
RIK-31: Uniform distribution of flake graphite and compound carbide with P and V in the pearlite structure.

RIK-32: Uniform distribution of flake graphite and compound carbide with P and V in the pearlite structure.

RIK-S (RIK-40, 41, 41LP, 42, 42A, 43, 44, 44A, 45, 46, 47)

RIK-S is gray cast iron which has excellent physical and mechanical properties achieved through special refining technology without the addition of alloying elements. It has suitable modulus of elasticity and hardness, running-in property and relatively good shock-resistance leading to its wide acceptance as a ring material, in automobiles, vessels, agricultural machinery, compressors and industrial machinery. In the structure of **RIK-S**, flake graphite or massive graphite which has self-lubricating and oil retaining properties is distributed uniformly in the pearlitic structure.

Material	Applicable Piston Ring Size (mmφ)	Pistion Ring Characteristics Modulus of Elasticity (GPa)	Transverse Rupture Strength (MPa)	Hardness	Tension Decrease (%)	Chemical Composition (%) T.C.	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Application
RIK-40	200 max.	93	343min	HRB 95~107	10 max.	3.3~3.9	1.7~3.2	0.5~1.0	0.2~0.6	0.12 max.	0.5 max.	—	—	—	—	Automobile, agricultural machinery
RIK-41	200 max.	93	392min	HRB 90~100	10 max.	2.9~3.5	1.6~2.6	0.5~1.0	0.2~0.6	0.12 max.	0.5 max.	—	—	—	—	Hydraulic and pneumatic equipment
RIK-41L.P.	40 max.	93	392min	HRB 91~100	10 max.	2.9~3.5	1.6~2.6	0.5~1.0	0.10~0.22	0.12 max.	0.5 max.	—	—	—	—	Seal ring for torqul converter
RIK-42	200~400	103	392min	HRB 93~105	15 max.	2.9~3.5	1.8~3.0	0.5~1.0	0.2~0.6	0.12 max.	0.5 max.	—	—	—	—	Medium size main marine engine, large size auxiliary marine engine
RIK-42A	200~400	118	441min	HRB 87~100	15 max.	2.8~3.4	1.4~2.4	0.5~1.0	0.2~0.6	0.12 max.	0.5 max.	—	—	—	—	Medium size main marine engine, large size auxiliary marine engine
RIK-43	200~400	118	441min	HRB 85~100	15 max.	2.8~3.4	1.6~2.6	0.5~1.0	0.2~0.6	0.12 max.	0.5 max.	—	—	—	—	Medium size main marine engine, large size auxiliary marine engine
RIK-44	400 min.	108	441min	HB 187~249	15 max.	2.8~3.4	1.3~3.0	0.5~1.0	0.2~0.6	0.12 max.	0.5 max.	—	—	—	—	Large size main marine engine, compressor
RIK-44A	400 min.	127	441min	HB 201~249	15 max.	2.8~3.4	1.3~2.0	0.5~1.0	0.2~0.6	0.12 max.	0.5 max.	—	—	—	—	Large size main engine, compressor
RIK-45	400 min.	123	441min	HB 178~235	15 max.	2.8~3.4	1.1~2.1	0.5~1.0	0.2~0.6	0.12 max.	0.5 max.	—	—	0.3~0.8	—	Large size main marine engine, compressor
RIK-46	400 max.	137	490min	HRB 97~110	15 max.	2.8~3.4	1.1~2.1	0.5~1.0	0.25 max.	0.12 max.	0.5 max.	—	0.3~0.7	0.6~1.2	—	Small size ring up to 30mm, 1st ring for small size and medium size Diesel engine
RIK-47	400 min.	137	588min	HB 201~255	15 max.	2.5~3.1	1.1~1.7	0.5~1.0	0.25 max.	0.12 max.	0.5 max.	—	0.3~0.7	0.6~1.2	—	Medium and low speed internal combustion engine



RIK-40: Uniform distribution of flake or massive graphite in the pearlite structure.

RIK-41: Uniform distribution of flake graphite in the pearlite structure.

RIK-41LP: Less containing steadite (eutectic of ferrite and iron phasphide) than RIK-41.

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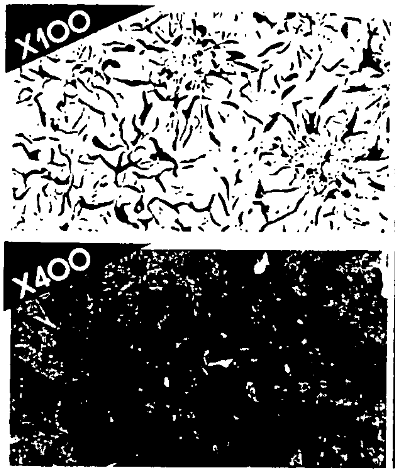
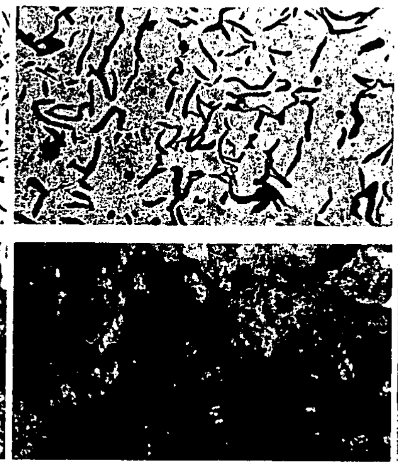
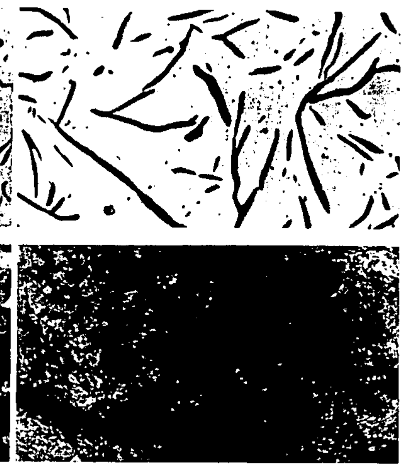


RIK-42: Uniform distribution of flake graphite in the pearlite structure.

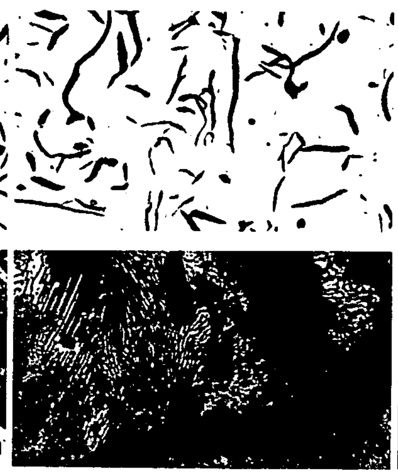


RIK-42A: Uniform distribution of flake gaphite in the pearlite structure.

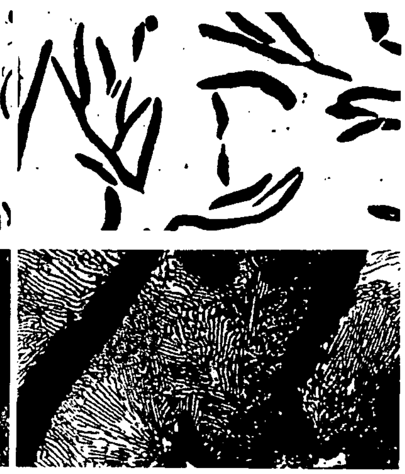


RIK-43: Uniform distribution of flake gaphite in the pearlite structure.

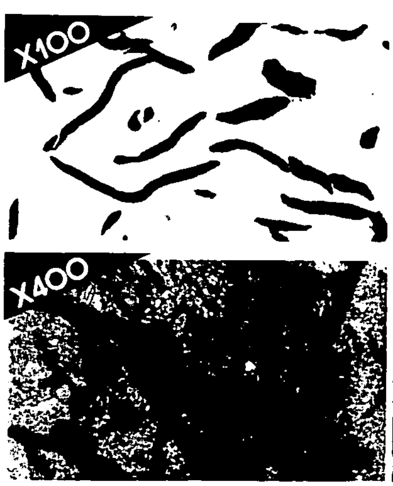
RIK-44: Uniform distribution of flake graphite in the pearlite structure.



RIK-44A: Uniform distribution of flake graphite in the pearlite structure.



RIK-45: Uniform distribution of flake graphite in the pearlite structure.



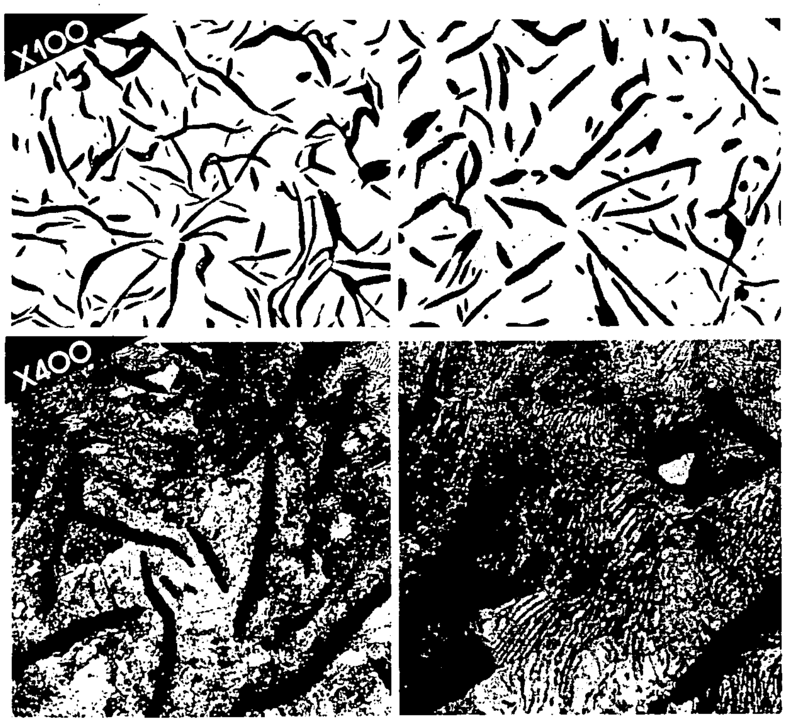
RIK-46: Uniform distribution of flake graphite in the fine pearlite structure.

RIK-47: Uniform distribution of flake graphite in the pearlite structure.

RIK (RIK-50, 50LH)

RIK(RIK-50) is specially designed not to damage mating materials and suitable for rings in hydraulic cylinders and metallic packing materials in vessels. RIK-50 contains relatively high amount of graphite which shows good oil retaining and self-lubricating properties. The amount of steadite which tends to damage the mating material is reduced as low as possible.

	Piston Ring Characteristics					Chemical Composition (%)											
Material	Applicable Piston Ring Size (mmϕ)	Modulus of Elasticity (GPa)	Transverse Rupture Strength (MPa)	Hardness	Tension Decrease (%)	T.C.	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Application
RIK-50	300 max.	83	294 min.	HRB 85~100		3.1~4.1	1.6~3.1	0.5~1.0	0.15 max.	0.12 max.	—	—	—	—	—	Hydraulic cylinder packing, rod packing, etc. by which mating material is apt to be damaged.
RIK-50LH	800 max.	83	245 min.	HB 137~170		3.1~4.1	1.6~3.1	0.5~1.0	0.15 max.	0.12 max.	—	—	—	—	—	Applicable to piston ring and rod packing materials for hydraulic cylinders which prevent cylinders and rods from damage.



RIK-50: Uniform distribution of flake graphite in the pearlite structure.

RIK-50LH: Graphite flakes are distributed uniformly in the base of pearlite + ferrite.

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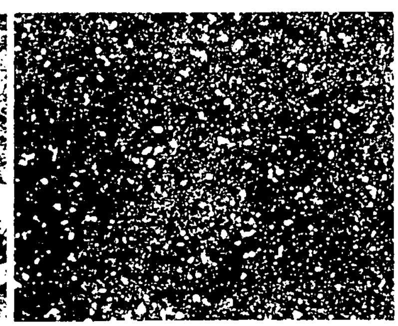
THERMO-RIK (THERMO-RIK-1, 2, 3, 4, 5, 6)

Excellent heat resistance and corrosion resistance are required for rings which are always exposed to high temperature gas and oil or molten metals. This includes seal rings in steam turbines, exhaust pipe fittings, and oil seals in superchargers and plunger rings in die casting machines. **THERMO-RIK** is a ring material developed for such applications.

Material	Piston Ring Characteristics: Applicable Piston Ring Size (mmϕ)	Modulus of Elasticity (GPa)	Hardness (HRC)	Tension Decrease (%)	Chemical Composition (%): C	Si	Mn	P	S	Cr	Ni	Mo	V	W	Application
THERMO-RIK-1	Not specified	196	35 ~ 50	10% max. at 400°C × 10 Hr.	0.15 ~ 0.20	0.50 ~ max.	0.5 ~ 1.0	0.04 max.	0.03 max.	10 ~ 13	—	0.3 ~ 0.9	0.1 ~ 0.4	—	Seal ring for low temperature steam turbine
THERMO-RIK-2	Not specified	196	20 min.	2% max. at 500°C × 100 Hr.	0.08 max.	1.00 max.	2.00 max.	0.04 max.	0.03 max.	13.5 ~ 16.0	24.0 ~ 27.0	1.00 ~ 1.50	0.1 ~ 0.5	Ti 1.90 ~ 2.35	Seal ring for high temperature (500°C) exhaust pipe
THERMO-RIK-3	Not specified	196	45 ~ 60	10% max. at 500°C × 10 Hr.	0.80 ~ 0.90	0.40 max.	0.40 max.	0.03 max.	0.03 max.	3.80 ~ 4.50	—	4.50 ~ 5.50	1.60 ~ 2.20	5.50 ~ 6.70	Oil seal for supercharger
THERMO-RIK-4	Not specified	196	40 ~ 50	5% max. at 450°C × 100 Hr.	0.32 ~ 0.42	0.80 ~ 1.20	0.50 max.	0.03 max.	0.03 max.	4.50 ~ 5.50	—	1.00 ~ 1.60	0.50 ~ 1.20	—	Piston ring for die casting machine
THERMO-RIK-5	Not specified	196	24 ~ 35		0.32 ~ 0.42	1.0 max.	1.00 ~ 2.00	0.04 max.	0.03 max.	19.0 ~ 21.0	19.0 ~ 21.0	3.5 ~ 4.5	Co 40.0 min.	3.5 ~ 4.5	Seal rings for steam turbines
THERMO-RIK-6	Not specified	196	23 ~ 33		0.08 max.	1.5 max.	1.00 max.	0.03 max.	0.03 max.	16.0 ~ 20.0	35.0 ~ 39.0	2.50 ~ 3.50	Co 18.0 ~ 22.0	Ti 2.30 ~ 2.90	
THERMO-RIK-20	Not specified	196	41 ~ 50		0.05 ~ 0.15	0.40 max.	1.00 ~ 2.00	0.04 max.	0.03 max.	19.0 ~ 21.0	9.0 ~ 11.0		Co	14.0 ~ 16.0	Seal rings for

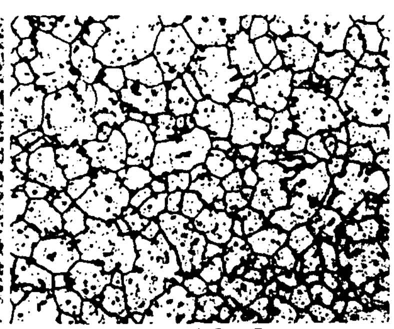
THERMO-RIK 1: Quenched and tempered.

THERMO-RIK 2: After solution heat treatment and precipitation age-hardening treatment.

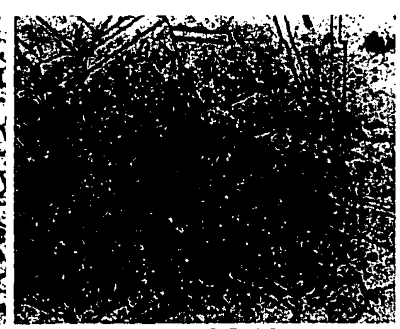


THERMO-RIK 3: Quenched and tempered.

THERMO-RIK 4: Quenched and tempered.



THERMO-RIK 5

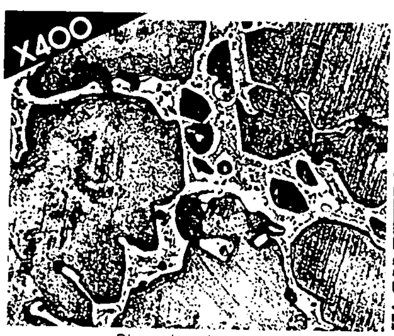


THERMO-RIK 6

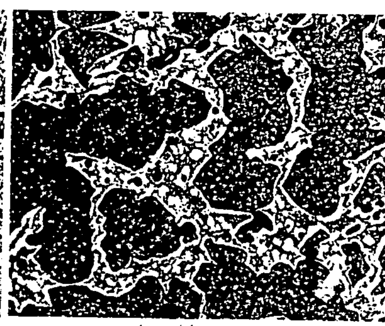
RIK-LOY Bronze

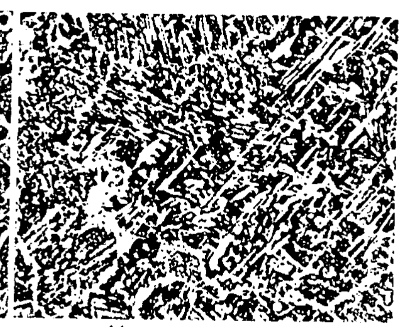
RIK-LOY bronze is an effective material for oil seals and seal rings which are required to have self-lubricating and corrosion resistant properties, as applied in compressors and pumps.

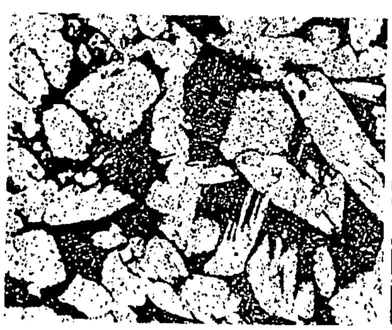
Material	Applicable Piston Ring Size (mmφ)	Modulus of Elasticity (GPa)	Hardness H_RB	Cu	Sn	Zn	Pb	P	Mn	Fe	Al	Ni	Si	Impurities	Application
	Piston Ring Characteristics			Chemical Composition (%)											
• Phosphor-Bronze															
RP-2A	400 max.	78	40 min. (H_B70 min)	Balance	12~17	0.5 max.	—	0.15 max.	—	—	—	—	—	2.0 max.	Equivalent to JIS H5113, PBC2A. Good wear resistance and corrosion resistance.
RP-3	400 min.	78	30 min. (H_B50 min)	Balance	8~13	0.5 max.	—	0.15 max.	—	—	—	—	—	2.0 max.	
• Lead Bronze															
RL-2A	Not specified	78	40 min. (H_B70 min)	Balance	12~17	—	4~8	—	—	—	—	—	—	3.0 max.	Good anti-scuffing property against soft steel cylinder, Metal packing for compressor, etc.
RL-3	Not specified	78	25 min. (H_B50 min)	Balance	10~15	—	8~12	—	—	—	—	—	—	3.0 max.	
RL-4	Not specified	—	(H_B60 min)	Balance	9~11	—	0.5~3.0	—	—	—	—	—	—	3.0 max.	
• Manganese Bronze															
RMn	Not specified	93	90~100	57~60	0.3 max.	29~38	0.5~1.0		2.0~3.5	0.35 max.	0.5~2.0	1.0~2.5	0.7~1.2		Oil seal for rotary shaft
• Aluminum Bronze															
RAl	Not specified	93	H_B120~150 (10/1000)	78 min.					1.5 max.	2.5~5.0	8.0~10.5	1.0~3.0			Guide ring for piling hammer, etc.



Phosphor bronze.


Lead bronze.


Manganese bronze.


Aluminum bronze.


Tin bronze

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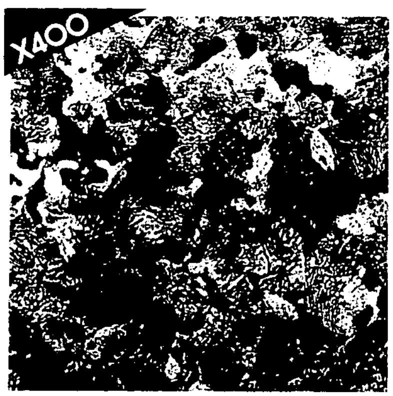
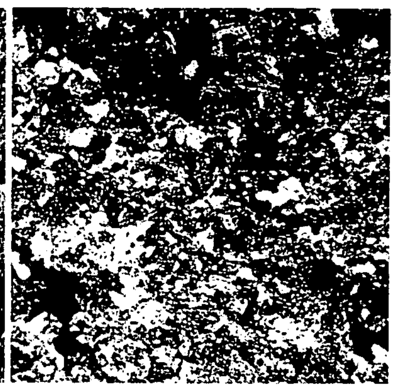
SINTER-RIK (SINTER-RIK Powder Metal Materials)

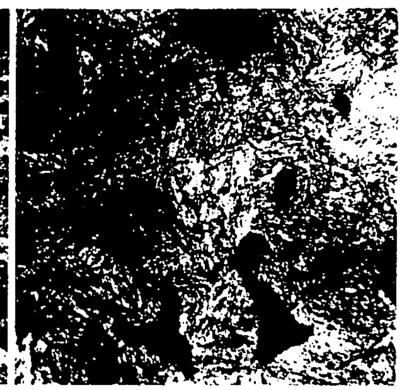
SINTER-RIK SRF-11 is a piston ring material developed for shock absorbers and compressors. It has high strength and Cu-containing homogeneous pearlitic structure in which the Mo rich areas, sulfide components and round voids are distributed uniformly, therefore it shows good wear resistance and machinability.

Material	Piston Ring Characteristics: Applicable Piston Ring Size (mmφ)	Modulus of Elasticity (GPa)	Transverse Rupture Strength (MPa)	Tension Decrease (%)	Hardness (R-15N)	Density g/c.c.	Chemical Composition (%): T.C.	Cu	S	Mo	Others	Fe	Application
SRF-11	Not specified	108	588 min.	10 max.	45 min.	6.4 ±0.25	0.6~1.2	2.5~3.0	0.8~1.2	0.25~0.35	2 max.	Balance	Piston ring for shock absorber and compressor
SRF-22	Not specified	118	785 min.	10 max.	50 min.	6.8 ±0.25	0.7~1.2	Cr 2.0~5.0		0.2~1.0	2 max.	Balance	Piston rings for small 2-cycle engines and seal rings for turbo suction
SRF-31	40 max.	127	981 min.	7 max.	60 min.	7.0 ±0.25	0.2 max.	Ni 15~20	Co 5~10	3~7	5 max	Balance	Seal rings for turbo discharge



SRF-11


SRF-22


SRF-31

4. PISTON RING SURFACE TREATMENT

Metallic materials and plastic products are reinforced and improved by proper surface treatment.

RIKEN manufactures and supplies piston rings and seal rings of top quality and performance. This is made possible by using a wide range of materials and utilizing its accumulated technology in the field

● Typical Surface Treatment Technology for Piston Rings

Type of Surfase Treatment				Application Applicable Engine									
Surface		Symbol	Hardness	Rust prevention (used together with rust preventives)	Initial break-in	Wear resistance	Side wear prevention	Side stick prevention	Aluminum alloy cylinder	Inner grove wear prevention	Gasoline engine Unleaded	Gasoline engine Leaded	Disel engine
Electro-plating	Hard chromium plating (Sliding faces)	Cr	800 ~ 1,100		○					○	○	○	
	Side chromium plating		800 ~ 1,100				○				○		○
	Circumferential inside chromium plating		800 ~ 1,100							○		○	○
	Tin plating	Sn	10 ~ 30		○						○		○
	Copper plating	Cu	90 ~ 620		○								○
Heat treatment	Nitriding	GN	700<			○	○				○	○	○
Deposition	Ion plating		1,200 or more			○					○	○	○
Composite electro-plating	Nickel base	CPN	800 ~ 1100			○						○	
Spraying	Metal spraying	RF	700<			○						○	○
	Ceramic spraying	RF	700<			○						○	○
Spray coat	TUFRIK®							○			○	○	
Compound processing	Phosphoric Zinc film	PRK-10	—	○							○	○	○
		RPK-11	—	○							○	○	○
		PRK-12	—	○			○	○			○		
	Phosphoric manganese film	PRK-25	—	○	○		○	○			○	○	
		RPK-26	—	○	○		○	○			○	○	
		PRK-27	—	○	○		○	○			○	○	
	Ferox treatment	PRK-30	—	○							○	○	○
Electro-plating+ Reverse current treatment	QB chromium plating	QBC	800 ~ 1,100		○	○					○	○	

A. Hard Chromium Plating (Cr)

Hard Chromium Plating (Cr)

The hard chromium plating layer has excellent characteristics which combine the original properties of chromium metal with the advantages of electro-deposits. The main features of hard chromium plating are as follows:

1. Extremely high hardness of HmV (Micro Vickers) 800 to 1,100 (cf. gray cast iron: 220 to 270).
2. High melting point of approx. 1,800℃ (cf. cast iron: 1,200℃).
3. Good thermal conductivity and corrosion resistance.
4. Low friction factor and excellent wear resistance. Such features are very effective in preventing piston ring wear.

With the development of this hard chromium plating, engine performance has been greatly improved. It is applied to piston rings for medium sized engines as well as small sized engines. Porous chromium plating which has oil retaining properties is used for high pressure compressors.

●Wear resistance of hard chromium plating

The following table shows the results of friction and wear tests on high grade cast iron and hard chromium plating. Gray cast iron was used for the mating material. As shown, it is evident that wear resistance of hard chromium plating is about 7 to 8 times higher than cast iron.

Side surfaces subject to high temperatures and high impact pressure (such as the 1st ring) tend to wear because of severe impact and friction in the ring groove of the piston during operation. If side surfaces are worn, a gastight state cannot be maintained and blow-by amount and oil consumption increase while horsepower decreases. Thus, adequate measures should be taken to prevent wear. RIKEN's **RIK-A**, **HI-RIK**, **RIK-DITE**, are extremely effective ring materials for such side face wear. Hard chromium plating can also be applied to side surfaces to obtain wear resistance.

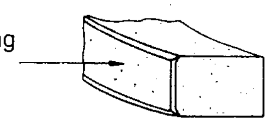
●Chromium plating on piston rings for internal combustion engines

(1) Thickness of plating
The thickness of plating differs depending upon the characteristics and type of engine. However, unless otherwise stated, it is specified according to JIS (refer to following table).

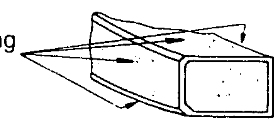
(2) Hardness of plating
Unless otherwise specified, the hardness of plating is Hv (200) 800 minimum.

Nominal Plating Thickness	Plating Thickness mm	Applications
0.05	0.05min.	Gasoline engine compressor
0.07	0.07min.	Gasoline engine and Diesel engine
0.10	0.10min.	Gasoline engine and Diesel engine
0.15	0.15min.	Diesel engine and engines for special use
0.20	0.20min.	Marine Diesel engine

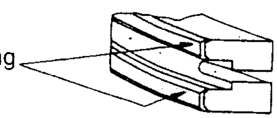
Hard chromium plating on working face



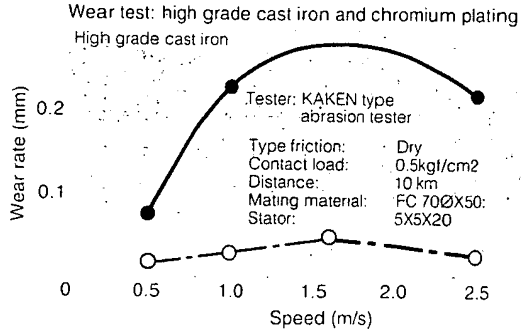
Hard chromium plating on all faces (4 faces)



Hard chromium plating on working face

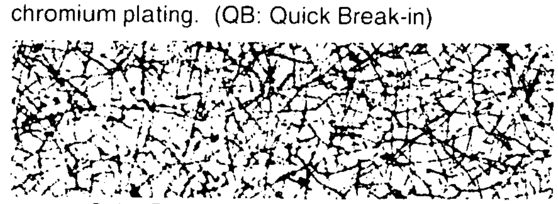


Wear test: high grade cast iron and chromium plating



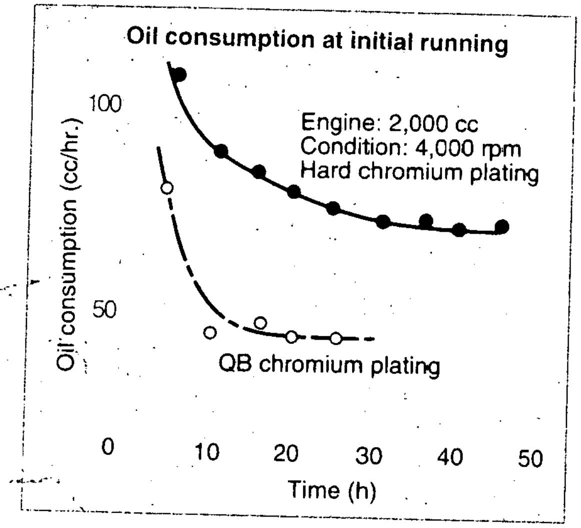
QB chromium plating (QBC)

QB chromium plating has shallower and finer porous layers than the above mentioned porous chromium plating. The following photo shows a typical structure in which channels run like mesh and retain the lubrication oil to give wettability.
QB plating gives better running-in properties than hard chromium plating. Moreover, it is effective in preventing scuffing in the period of initial running-in because of its wettability. In addition, it has sufficient wear resistance which is a feature of hard chromium plating. (QB: Quick Break-in)

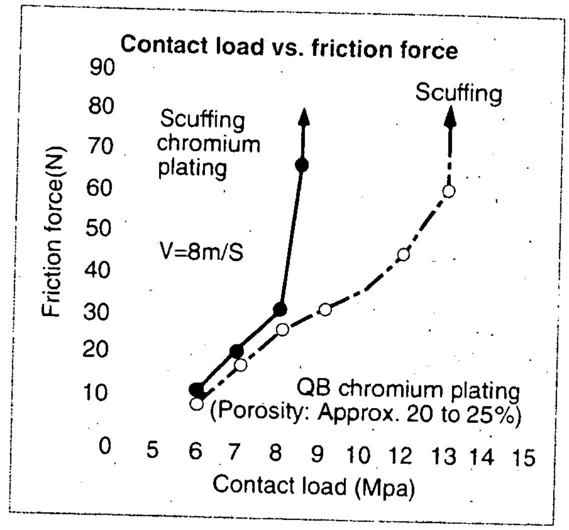


Quick Break-in Porous Chromium Plating

●**Initial running-in property**
Initial running-in property between QB and hard chromium plating was compared in terms of operation period until oil consumption stabilized. The result is as shown in the following figure. It has been proved that oil consumption with the QB chromium plating stabilized after approx. 10 hrs. and it gives better oil consumption property in a shorter time than the hard chromium plated ring.

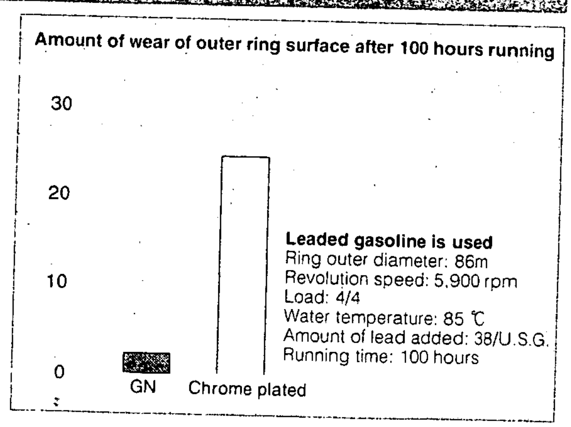


●Anti-scuffing property
QB chromium plating retains oil so that QB chromium has better anti-scuffing properties. The anti-scuffing property of the QB chromium plated ring was compared with the hard chromium plated ring. The result is as shown in the following figure, and it has been proven that the QB chromium plated ring withstands a heavier load before scuffing occurs.



B. GN (Nitrided)

Piston rings are now required to have a much higher level of quality to stand up to the demands made on them by automobile engines which now have to operate at higher speeds and under greater loads. GN piston rings have been developed to meet these requirements. The mother metal of the GN piston ring is (RIK-SP3) 17% Cr martensite stainless steel. The metal is treated with a gas nitriding process.
The surface is covered with an extremely hard layer of nitrided metal which is formed by Cr. and Fe., and this layer demonstrates excellent anti-wear and anti-scuffing properties.



Main Features

1. A very hard layer is formed and anti-wear property is excellent.
2. The anti-scuffing property with the cylinder liner (Fc metal) is very good.
3. It has good anti-corrosive and anti-wear properties.
4. Upper and lower surfaces both have outstandingly good anti-wear properties.

C. Ion Plating (PVD)

In recent years, in terms of tribology, engines are facing a very adverse environment. The need is for tremendous improvements in wear and scuffing-resistant engines. Ion plating films have been developed to meet this need.

Ion plating is one form of ceramic coating film. It features excellent wear and scuffing-resistance, and it is an ideal surface treatment with low friction coefficient.

Features

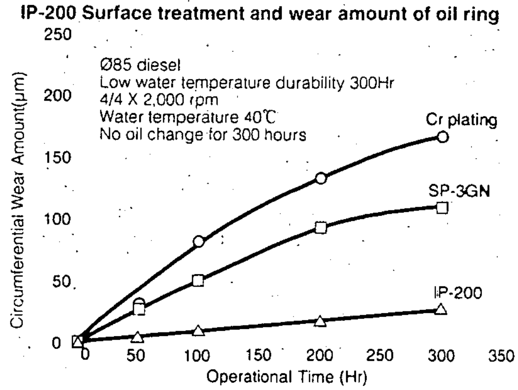
1. High degree of hardness, and excellent wear resistance
2. It give a high degree of anti-scuffing properties for various liner materials.
3. The friction coefficient is low.

Ion Plating Treatment

RIKEN Ion Plating Film Variations

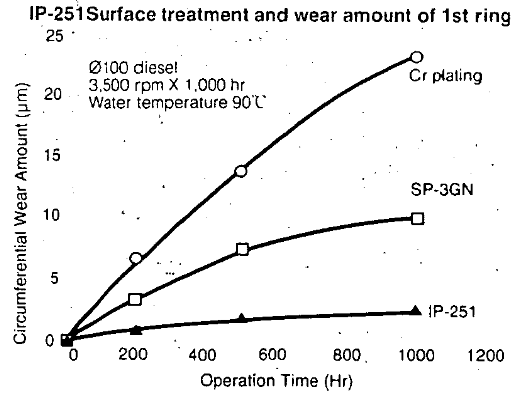
	IP-100	IP-200	IP-251
Composition	TiN	CrN	CrN
Color	Gold	Metallic Silver	Metallic Silver
Hardness	1700-2300	1500-2000	850-1150
Film Thickness	Difficult to achieve thick film Less than 10μm	Possible to form thick film Up to 40μm	Possible to form thick film Up to 70μm
Application Range	1st ring for high output gasoline engines	Oil control ring for diesel engines and gasoline engines	1st ring for diesel engines

IP-200 Surface treatment and wear amount of oil ring



The IP-200 CrN film anti-wear property is 8 times that of high hardness chromium plating, 5 times that of SP-3 + nitriding treatment, and it demonstrates good anti-wear properties.

IP-251 Surface treatment and wear amount of 1st ring



The IP-251 CrN film anti-wear property is 9 times that of high hardness chromium plating, 5 times that of SP-3 + nitriding treatment, and it demonstrates good anti-wear properties.
Cr plating

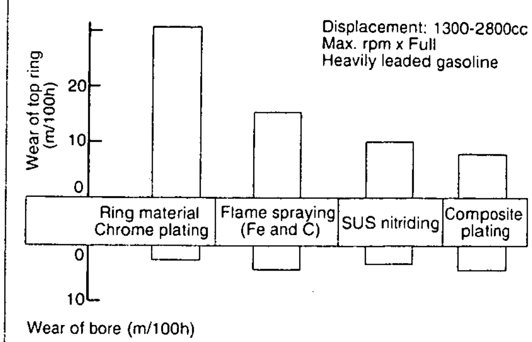
D. CPN (Ni-Based Composite Plating)

Hard chrome plating is not satisfactory in terms of wear resistance so far as the sealing surfaces of piston rings of engines using leaded gasoline or of diesel engines are concerned.
Piston rings of increased durability are in demand to realize maintenance-free engines. The possibilities of FC sleeveless Al alloy engines have also been studied. CPN has been developed to meet these requirements.
CPN is a thermosetting type Ni-base dispersed alloy plating where particles of silicon nitride (Si_3N_4) are dispersed to accomplish surface treatment of good wear resistance, anti-scuffing property, corrosion resistance, and less bore wear.

Main Features:

1. Has the same level of hardness as hard chromium plating for good wear resistance.
2. Excellent anti-scuffing property and a very low level of bore wear permitting the material to be used in FC and Al alloy cylinder liners.
3. Ni, Co, and P alloy base for very good corrosion resistance.

■ Comparison of Wear of Ring and Bore



E. Plasma Spraying and Flame Spraying (RF)

In recent years, plasma and flame spray coatings have been applied to piston rings as surface treatment. A groove is provided on the working face of the piston ring. Then the coating material is sprayed for the purpose of giving wear resistance and anti-scuffing property.
Types of spraying are as follows:
RF-1300 Ceramic, plasma spraying
RF-2300 Plasma spraying (molybdenum base with ceramic)
RF-4300 Plasma spraying (iron base with ceramic)

a) Ceramic plasma spraying

Ceramic spraying has been developed for rings applied in chromium plated liners. The conventional piston ring working face for chromium plated cylinder liners is the ring base metal (generally cast iron) or, at best, solid lubricants such as graphite are filled in the ring OD face groove. When such conventional piston rings are applied to the chromium plated cylinder liners, the piston ring tends to wear more than the cylinder liner. At present, actual down-time for inspection and maintenance of the engine is determined by the life of the piston ring rather than that of the cylinder liner. Therefore, running hours of the engine may be extended further if the wear resistance of the piston ring for the chromium plated cylinder liner is improved. The ceramic sprayed ring satisfies this purpose. The features of ceramics are as follows:

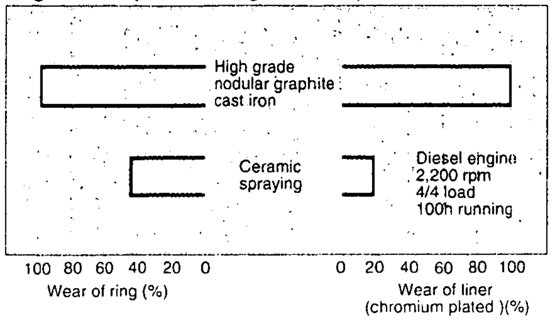
- High melting point of approx. 2,300℃
- High hardness of approx. 1,000HV (0.05)
- Better wear resistance

Ceramics which have such properties are sprayed onto the working face of the ring and a satisfactory effect is achieved. When used with a chromium plated cylinder liner, it shows excellent wear resistance, and reduces the wear of the chromium plated face on the mating cylinder liner. With this surface treatment of the piston ring, it is possible to avoid rapid wear of conventional piston rings and to extend the service life of the engine greatly.

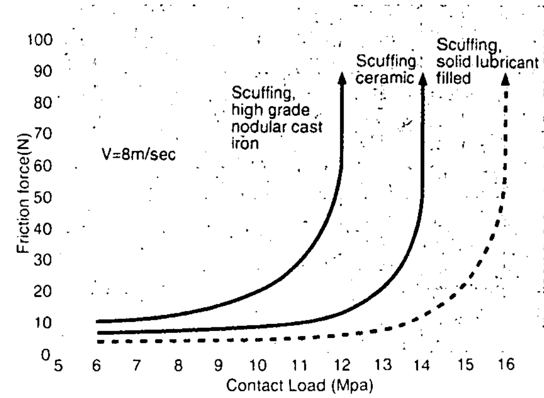
b) Plasma spraying of mixed materials

Mixed spraying materials are composed of several blending materials (such as ceramic, molybdenum, iron, etc.). It features combined wear resistance excelling that of chromium plating with good anti-scuffing property.
With the adoption of this plasma spraying, high film strength, good adhesion and excellent wear resistance surpassing that of molybdenum flame spraying are obtained.

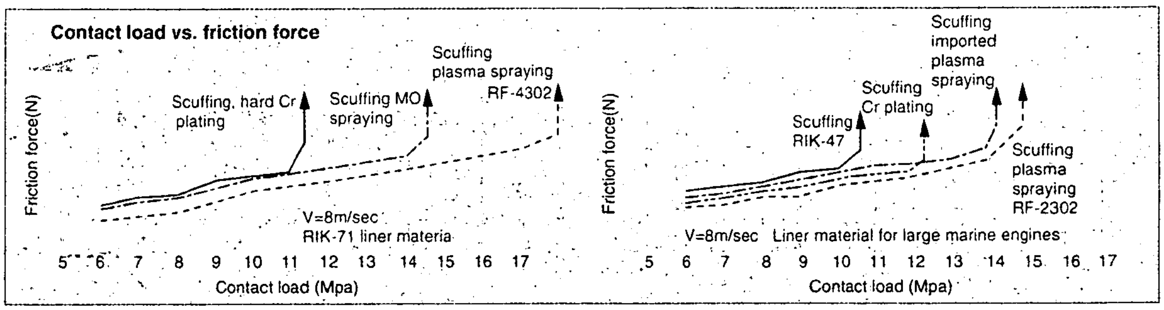
Engine test (wear of ring and liner)

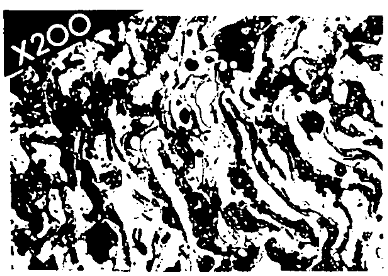


Contact load vs. friction force

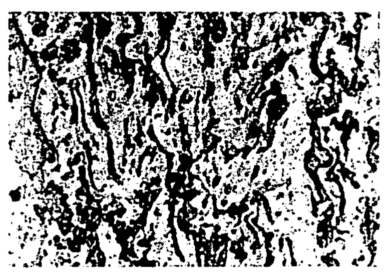


Contact load vs. friction force





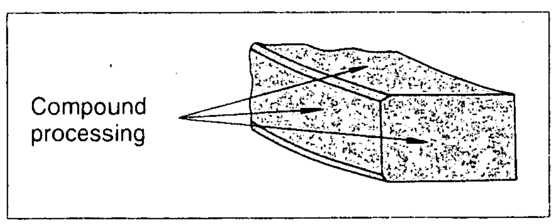
Example 1: Mixed spraying material (RF 2302)

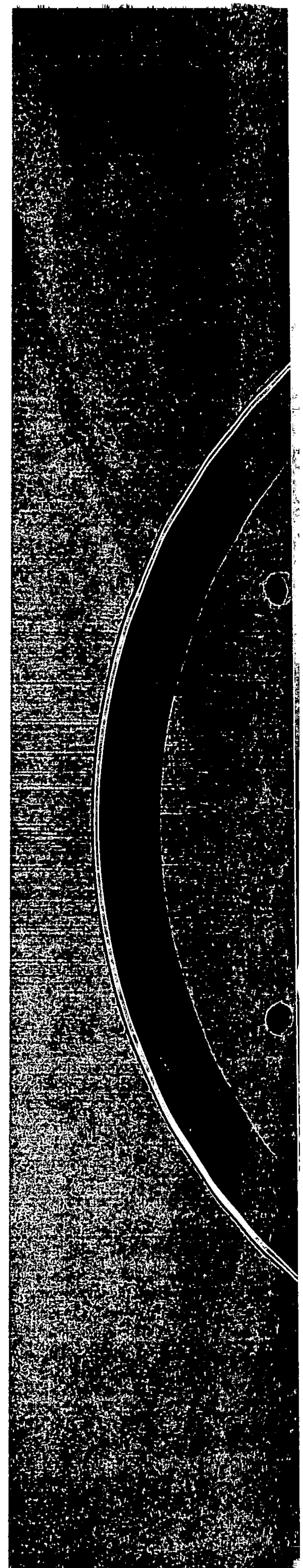


Example 3: Mixed spraying material (RF 4302)

F. Compound processing (RPK)

Compound processing is a process to form a film composed of accumulated layers of metal phosphate crystals. It is porous and relatively soft. Thus, it has sufficient oil retaining property and leads to proper running-in, even with insufficient oil supply during initial operating period. Moreover, it shows excellent anti-corrosive property and rust preventing effect. Compound processing treatment is carried out for most types of RIKEN





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